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(56) Documents Cited
GB 2124402 A US 5177807 A US 4237474 A

(58) Field of Search
UK CL (Edition N) G2J JGED , H1K KQAG
INT CL[6] G02B , H01L

(54) Optically coupling optical fibres to injection lasers

(57) The end (5) of an optical fibre (4) is held in alignment with an injection laser (3) by securing the fibre to an elongate support member (6) which is then secured to a substrate (2) to which the laser is also secured. The support member (6) is provided with a longitudinally extending open channel in the base of which the fibre (4) is secured with hard solder (7). Member (6) is subsequently secured to the substrate (2) by welds (12) to slide members (8) fixed on the substrate (2).

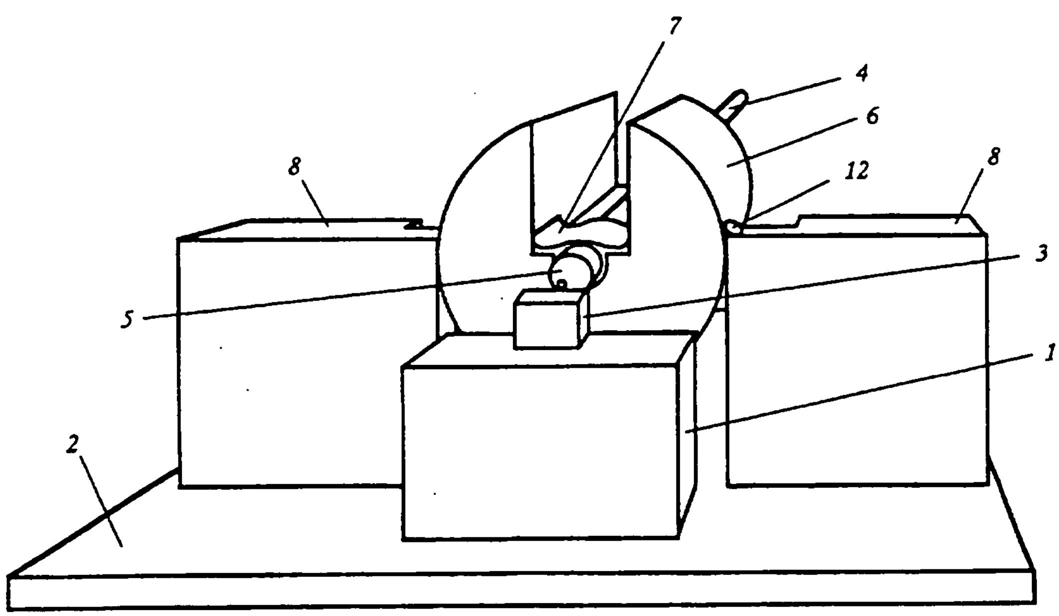

Fig. 1.

GB 2 296 100 A

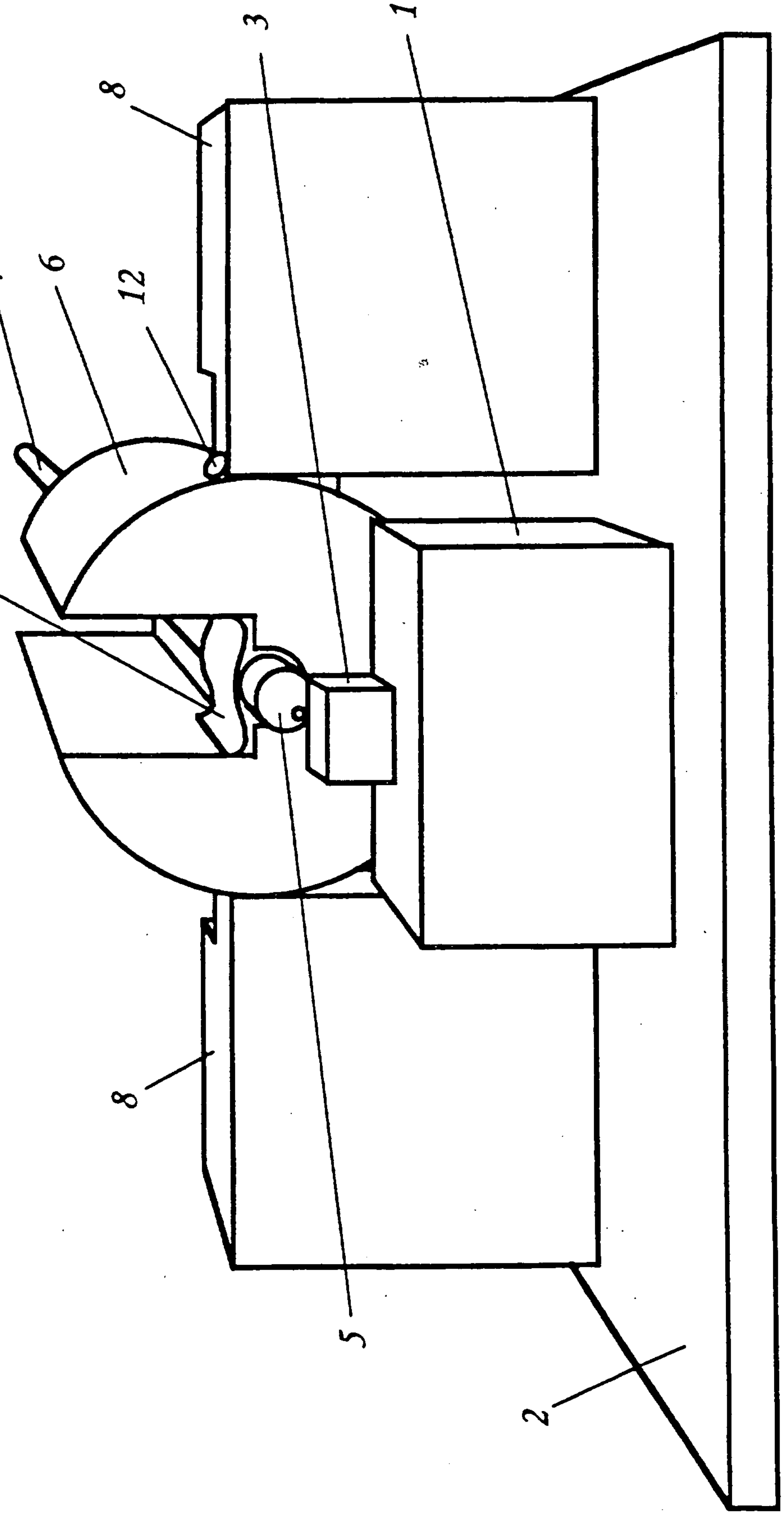

Fig. 1.

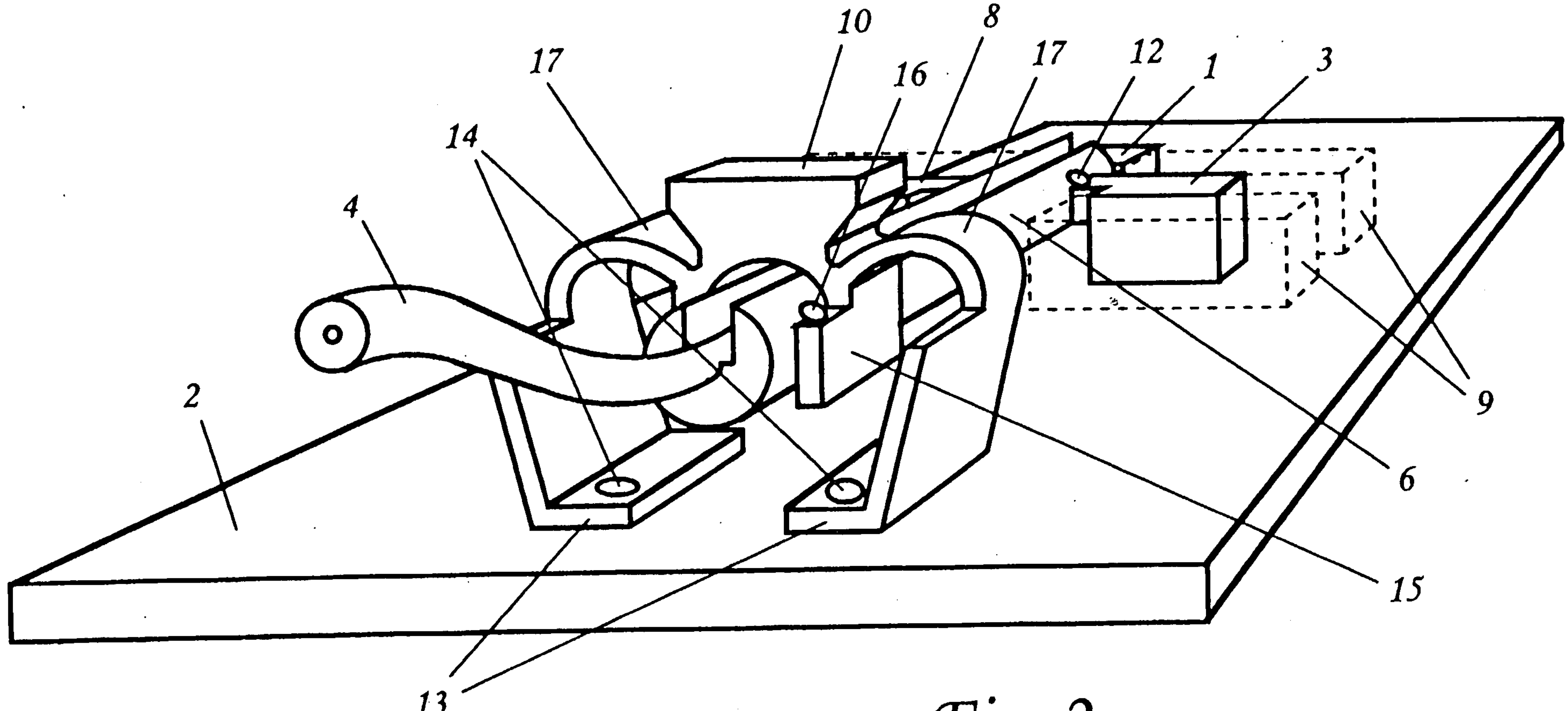

Fig. 2.

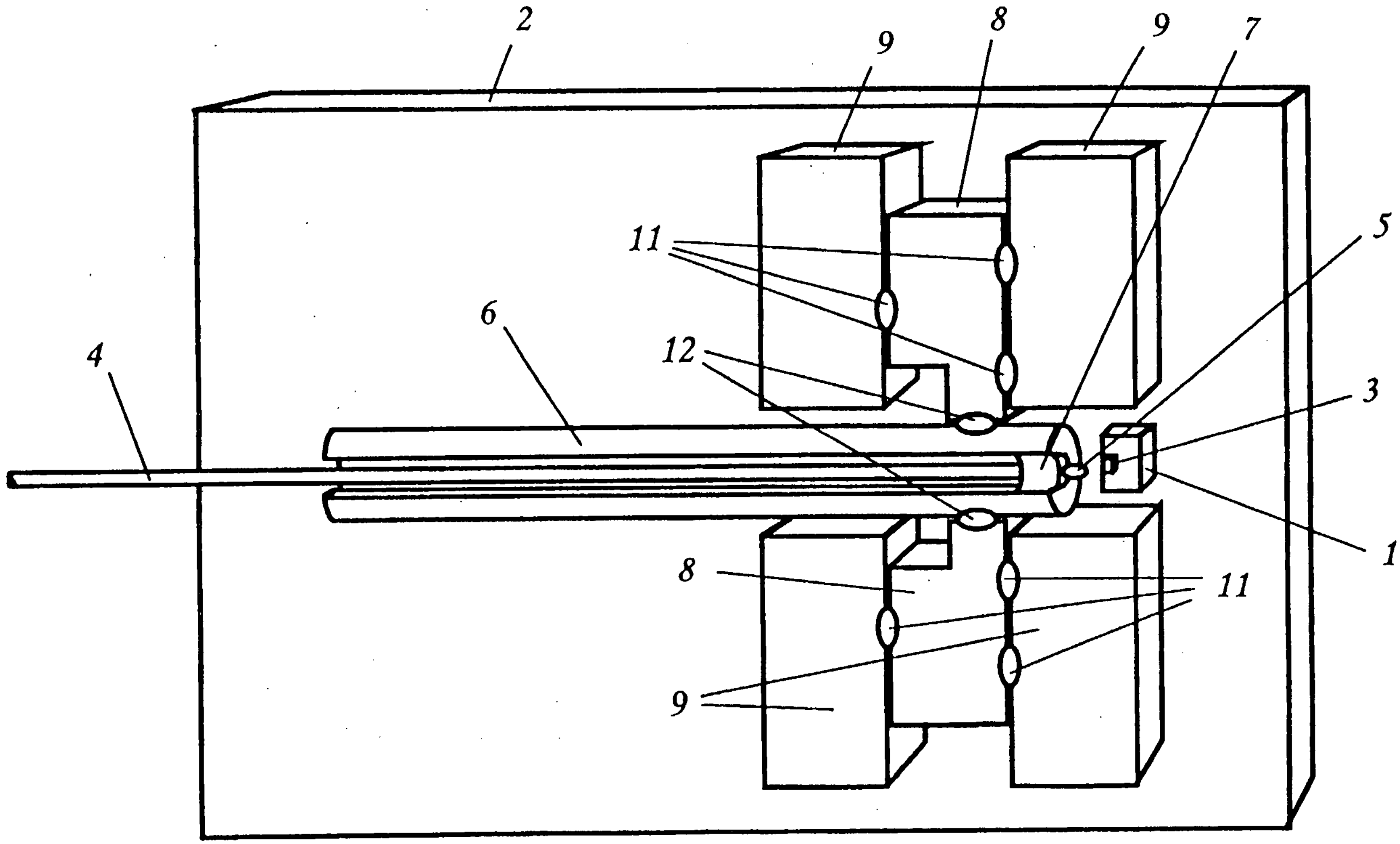

Fig. 3.

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OPTICALLY COUPLING OPTICAL FIBRES TO INJECTION LASERS

This invention relates to the optical coupling of optical fibres, generally single mode optical fibres, to injection lasers, and is particularly concerned with the achieving of high coupling efficiency and of long-term stability in the achieved coupling efficiency. Whilst it is generally advantageous to increase coupling efficiency, such an increase is generally achieved at the expense of an increased sensitivity of the coupling to the effects of malalignment, and this is liable to militate against stability of the coupling efficiency arising from stress-relief type movements provoked over the course of time for instance by thermal cycling. For many applications where high performance is required, the alignment between fibre and laser is required to be held constant to within about 0.1μm over a temperature range of -40° to + 85° C, and through several hundred thermal shocks over the same temperature range.

Light from the laser may be coupled directly into the end of the fibre, in which case the fibre end may have a lensed refracting surface, or the light may be coupled via a separate discrete lens, typically a ball lens.

One type of coupling assembly has the injection laser mounted on a substrate provided with a platform in front of the output facet of the laser, to which platform the fibre is directly soldered once it has been moved into the alignment position found to provide optimal coupling efficiency. A serious drawback liable to occur with this alignment method is that the fibre position is disturbed in the course of the

freezing of the solder pool by which it is secured to the platform. Such movement results from shrinkage effects that occur when the solder freezes, and generally the amount and direction of that movement is not predictable and reproducible. A resin may be used as an alternative to solder for the securing of the fibre to the platform, but this merely exchanges the movement problem engendered by the freezing of the solder with the movement problem engendered by the shrinkage occurring during the curing of the resin.

An alternative type of coupling assembly is described in GB 2 124 402 A to which attention is directed. In this assembly the fibre end is secured by solder in the bore of a length of hypodermic tubing, and then, once the fibre has been aligned, this tubing is secured to the platform by means of a saddle structure engaged around the tubing and laser beam welded to both the tubing and the platform. Movement of the fibre within the hypodermic tubing during the freezing of the solder does not disturb the final alignment of the fibre with respect to the laser because this alignment is not established until after such freezing of the solder has occurred. It is also to be noted that the heating involved in the laser beam welding is reasonably sharply localised, whereas if the fibre is secured in alignment by soldering, or by the thermally induced curing of a resin, the fibre is typically subjected to substantially higher temperatures while it is being so secured. Even so, it is found that the freezing of the weld-pool is liable to disturb significantly the alignment between fibre and laser. Using welding saddles and hypodermic tubes manufactured to a tolerance of ± 10 μm it has been found that the welding can result in displacement of up to 5 μm. Such displacements can be corrected by subsequent straining of the hypodermic tube, but this amount of straining leaves residual stresses in the tube which are liable to relax over the course of time in the presence of thermal cycling and/or thermal shock.

This problem of the relaxing of the strain in a strained hypodermic tube is only one of the mechanisms by which misalignment between

the fibre and the laser may develop in the course of time. The magnitude of this strain relief can be minimised, as for instance described in our co-pending patent application (patent application No 94/........... filed with this application and identified in our records as A P Janssen 9-1), by choice of a suitable construction and layout of components which minimise welding displacements and hence the amount of strain that has to be incorporated into the hypodermic tube in the first instance.

Another mechanism by which misalignment may develop over the course of time between the fibre and the laser is associated with stress relief in the solder that secure the fibre in the bore of the hypodermic tubing. When a soft solder is used, it is found that over the course of time, in the presence of thermal cycling and/or thermal shock, relative movement is liable to occur between the fibre and hypodermic tube. Solder creep is found to occur, possibly occasioned in part by uneveness of plating within the bore of the tube as the result of imperfect cleanliness, by the presence of voids in the solder, and by the effects of differential thermal expansion, radial expansion of the solder being constrained by the encircling tube wall. It might be thought that such solder creep could be avoided merely by replacing the soft solder with a hard solder, but this has not been found to be an acceptable solution because the stresses involved in the hard soldering of an optical fibre within such a hypodermic tube have been found so great as upon occasion to induce spontaneous fracture of the fibre close to the point at which its lensed end protrudes from the end of the tube.

The present invention is directed to circumventing this problem.

According to the present invention there is provided an optical fibre pigtailed injection laser package in which the end of an optical fibre pigtail into which light from an injection laser is optically coupled is secured in the base of an open channel extending longitudinally along an elongate support member that is itself subsequently secured to a substrate to which the injection laser is also secured.

One of the advantages of the open channel is that it is much easier to clean than the bore of a length of hypodermic tubing. Lack of cleanliness can adversely affect long term stability by introducing unwanted inhomogeneities in the medium, typically solder, by which the fibre is secured to its support member. This lack of cleanliness in the bore of a hypodermic tube support member can result in uneven plating of the bore of the tube, which in its turn can result in the formation of voids in the solder due to uneven wetting of the bore wall by the solder.

Another of the advantages of the open channel is that the medium that secures the fibre to the support member is not completely encircled by that support member, and so any mismatch between the thermal expansion of the securing medium and those of the fibre and the support member is more readily accommodated by the unconfined portion of the securing medium. The open channel also facilitates control over the amount and placing of the securing medium so that excessive thicknesses are avoided.

There follows a description of a method of securing the end of an optical fibre in position relative to an injection laser to provide substantially optimal coupling between the laser and the fibre, which method embodies the invention in a preferred form. The description refers to the accompanying drawings in which:-

> Figure 1 is a schematic perspective view of the assembly (excluding its saddle member) viewed from the laser end,
> Figure 2 is a schematic perspective view of the assembly viewed from the fibre end, and
> Figure 3 is a schematic perspective view of the assembly (excluding its saddle member) viewed from the top.

A diamond heat-sink 1 is mounted on a low thermal expansion coefficient substrate 2 made for instance of 'KOVAR'. On the heat-sink 1 is mounted an injection laser 3 with its output emission facet

substantially flush with a side edge of the diamond heat-sink. The laser emission is to be coupled into a single mode optical fibre 4 which is provided with a lensed end 5 in order to improve laser-to-fibre coupling efficiency. Near the lensed end 5, the optical fibre 4 is secured within an elongate support member, which is also preferably made of a low thermal expansion coefficient material. This support member has the form of a slotted rod 6. The optical fibre 4 is secured in the slot of this rod by means of a fillet 7 of solder positioned near the lensed end. Preferably this solder fillet 7 is a filet of gold tin hard solder Although hard soldering such a fibre within the bore of a hypodermic tube has been found to produce differential thermal expansion related stresses sufficient to risk spontaneous fracture of the fibre where it emerges from the solder, it is found that the stresses resulting from hard soldering the fibre in the bottom of the slotted rod are so much smaller that this sort of spontaneous fracture is not a problem. The reduction in stress is believed to be the result of the fact that in this instance the solder is not fully encircled by the rigid wall of low thermal expansion material: the outer surface of the solder being bounded only in part by such material, the remainder of the outer surface, the top part, being unconfined.

The lensed end 5 of the fibre 4 is required to be accurately aligned with respect to the laser 3 so as to provide substantially optimised optical coupling efficiency between them, and moreover that alignment is required to be maintained with minimal variation, as over the course of time, the assembly becomes subject to thermal cycling and thermal shock. Such alignment is provided by powering the laser 3, monitoring the level of power launched into the fibre 4 for the laser 3, and manipulating, with a micromanipulator (not shown), the slotted rod 6 to bring the fibre 4 into the position providing the maximum level of monitored power. At this stage the rod must be stably secured in a manner providing minimal disturbance of the alignment. The end of the slotted rod 7 nearer the lensed end 5 of the fibre 4 is secured by laser beam welding to two low thermal expansion slide members 8 that are themselves

fixed in position by laser beam welding to co-operating runners that are constituted by pairs of blocks 9 protruding from the substrate 2. (For convenience of illustration these blocks have not been depicted in Figure 1, they are depicted in Figure 3 and in Figure 2 they are depicted in broken outline only). Before they are secured, the slide members 8 slide in a direction at right angles to the axis of the slotted rod 6. The end of the slotted rod remote from the lensed end 5 of the fibre 4 is similarly secured by laser beam welding to a plastically deformable saddle member 10 that is laser beam welded to the substrate 2.

The sequence of assembly is first to use the micromanipulator to hold the slotted rod in its required position, and then to slide the slide members 8 into contact with the sides of the slotted rod 7. These are then moved away from contact by a controlled amount to provide a gap of a specific narrow width typically about 1 to 3 µm. The use of the two slide members enables these two gaps to be provided with a precision that is not conveniently attainable with a single piece part embracing the slotted rod having positioned each slide member to provide the required gap between it and the slotted rod. The slide members are secured to the blocks 9 by laser beam welds 11. The arrangement of the slide members and their blocks is such that weld contraction induced displacement is substantially confined to the axial direction of the fibre, thereby leaving the gaps between slide members and the slotted rod substantially unchanged. After the welding of the slide members to the blocks 9, the slotted rod 6 is secured to each slide member 8 by a single laser beam weld 12 straddling the precision gap between that slide member and the rod. In this way the transverse displacement of the rod during the making of these welds 12 is minimised, typically being kept to well under 1µm. (In the absence of the precision gaps, and using instead precision piece-parts manufactured to a tolerance of ± 10µm, the weld displacement would be up to 5µm).

Any such small transverse displacement as does occur in the making of the welds 12 is compensated by re-alignment brought

about with the aid of the deformable saddle 10. This saddle is positioned loosely around the slotted rod 6, and its two feet 13 are secured to the substrate by laser beam welds 14. Then the slotted rod is secured to two shoulders 15 of the saddle by two further laser beam welds 16 across gaps made as small as possible in order to minimise transverse weld displacement. The saddle is designed to allow plastic deformation to occur within two arms 17 connecting the shoulders 15 of the saddle to its feet 13. After the welding, the saddle and rod can be suitably re-positioned by deforming the saddle arms by pushing the assembly beyond the elastic limit of those arms with a suitable tool (not shown).

By making the substrate 2, the slotted rod 6, the slide members 8, their co-operating runner blocks 9, and the deformable saddle 10, all of the same low expansion material, such as KOVAR, the precise positioning of the end 5 of the optical fibre 4 relative to the laser should be substantially independent of temperature. If the assembly is heated or cooled, the rod will typically heat up or cool down more slowly than the substrate because of the finite thermal impedance presented to the flow of heat in or out of the rod by way of the saddle and slide members and their associated welds. This means that, during such heating or cooling of the assembly, the rod is liable to be at a different temperature from that of the substrate. Thermal expansion effect related stresses occasioned by this difference are accommodated principally by articulation of the saddle since the welds by which it is pinned to the substrate lie in a single straight line extending in a direction at right angles to the axis of the rod, whereas the slide members present a more rigid structure, the welds by which they are pinned to the runner blocks 9 lying in a pair of straight lines that are spaced apart in the axial direction of the rod.

Since KOVAR is not readily wetted by solder, the substrate 2 and the slotted rod 6 are both plated to improve solder wettability. This plating may for instance comprise a nickel layer of between 6 and 8μm thickness followed by a 2μm thick gold layer provided to protect the underlying nickel from oxidation. If the runner blocks 9 are

formed integrally with the substrate, they will also be plated. On the other hand, the slide members 8 and the deformable saddle 10 are preferably left unplated. This is so that they retain their matt surfaces and thus the more readily absorb the energy of the laser beam welding radiation.

CLAIMS:

1. An optical fibre pigtailed injection laser package in which the end of an optical fibre pigtail into which light from an injection laser is optically coupled is secured in the base of an open channel extending longitudinally along an elongate support member that is itself subsequently secured to a substrate to which the injection laser is also secured.

2. A package as claimed in claim 1, wherein the fibre pigtail is secured with solder in the channel.

3. A package as claimed in claim 2, wherein the solder is a hard solder.

4. A package as claimed in claim 3, wherein the solder is a gold-tin hard solder.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9425021.4

Relevant Technical Fields

(i) UK Cl (Ed.N) G2J (JGED) H1K (KQAG)

(ii) Int Cl (Ed.6) G02B, H01L

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Search Examiner
M K B REYNOLDS

Date of completion of Search
25 JANUARY 1995

Documents considered relevant following a search in respect of Claims :-
1 TO 4

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2124402 A	(STC) Figures 8 to 9, page 4	1 to 2
X	US 5177807 & EP 0481877 A	(THOMSON) whole document	1 to 2
X	US 4237474	(RCA) Figures 1 to 3, columns 2 to 4	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

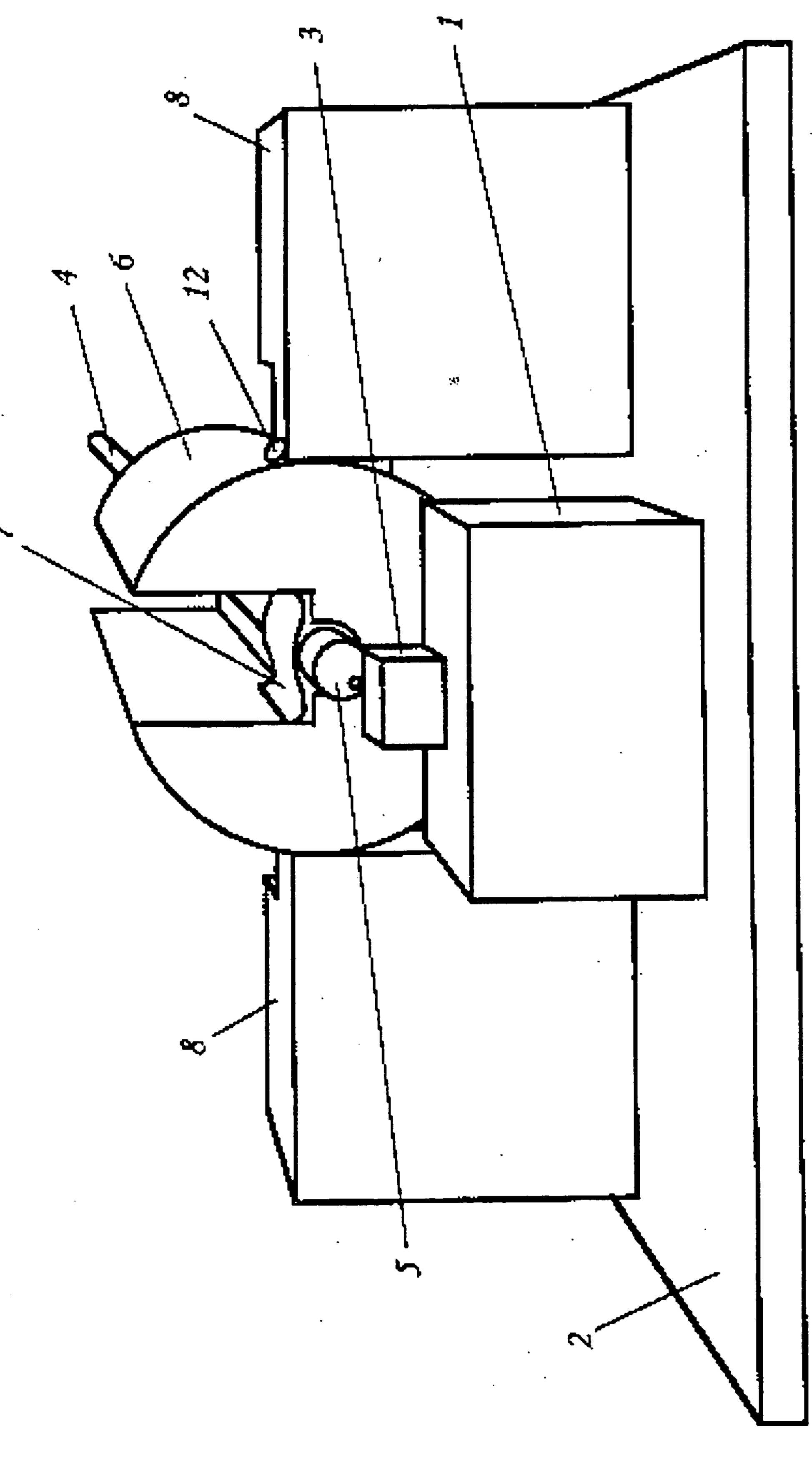

Fig. 1.

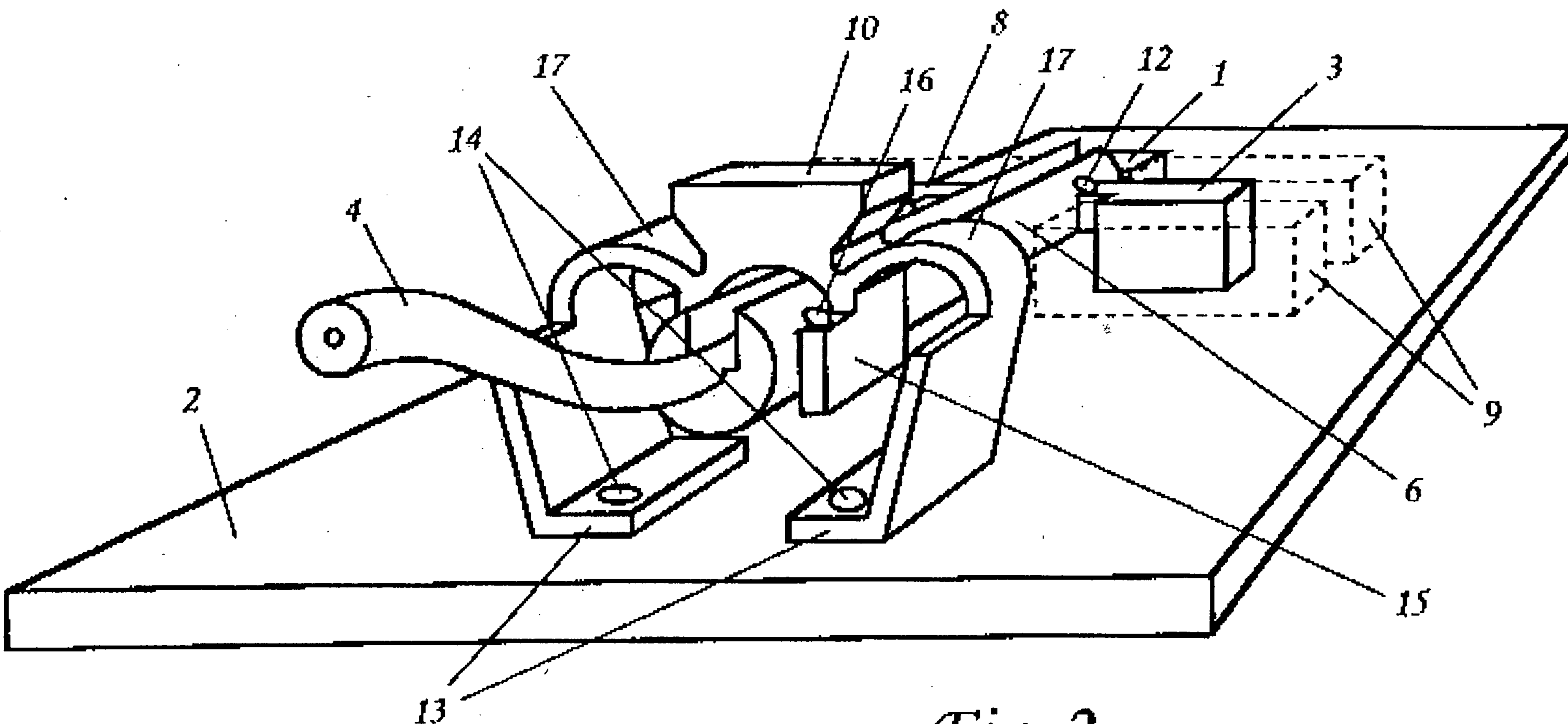

Fig. 2.

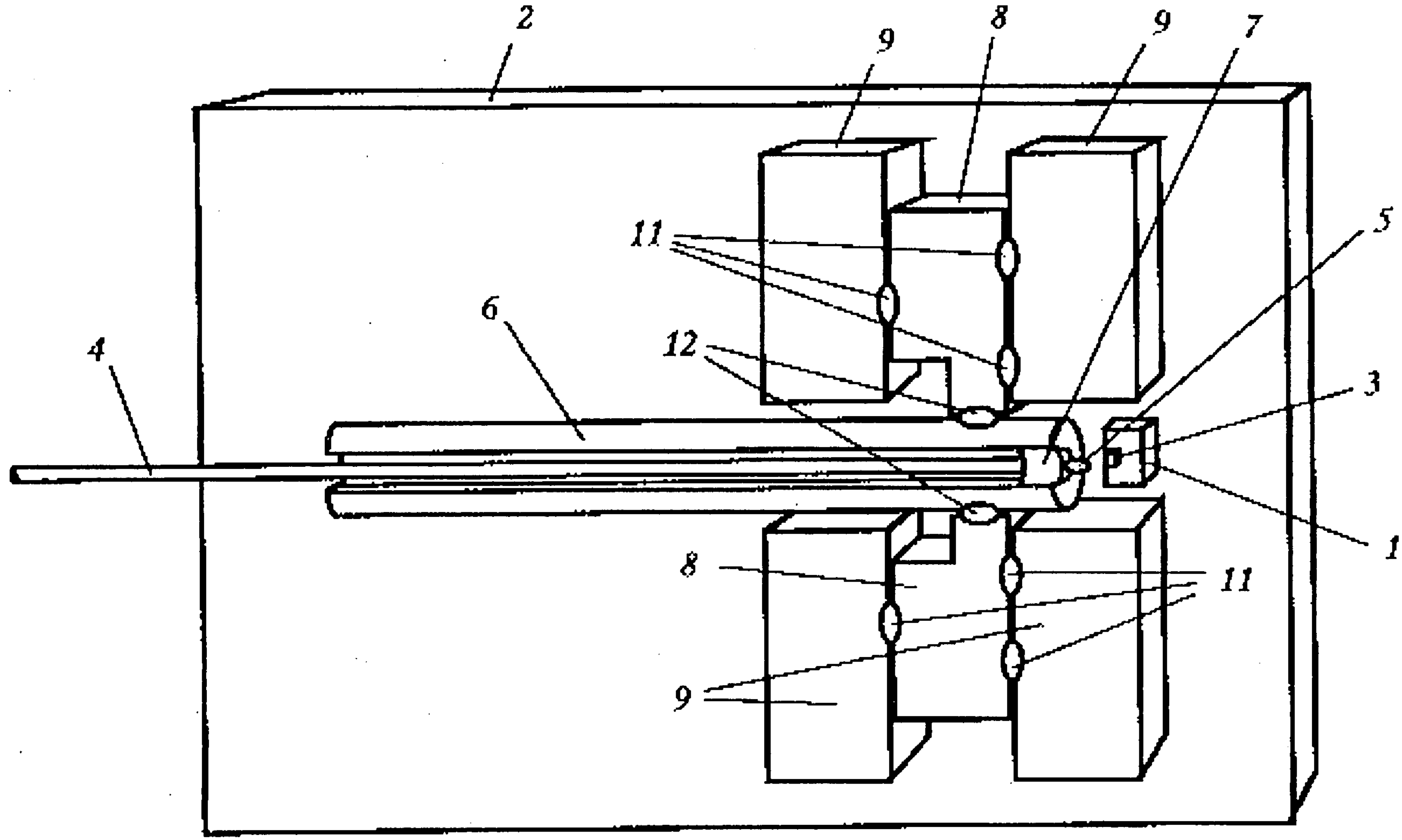

Fig. 3.